Astronomy & Astrophysics manuscript no. 4775text
January 19, 2007

Radio variability properties for radio sources

J. H. Fan[1,2], Y. Liu[1], Y. H. Yuan[1], T.X. Hua[1], H. G. Wang[1], Y. X. Wang[3], J. H. Yang[4], A. C. Gupta[5], J. Li[1], J.L. Zhou[1], S.X. Xu[1], and J.L. Chen[1]

[1] Center for Astrophysics, Guangzhou University, Guangzhou 510006, China
[2] Physics Institute, Hunan Normal University, Changsha, China
[3] College of Science and Trade, Guangzhou University, Guangzhou 511442, China
[4] Department of Physics and Electronics Science, Hunan University of Arts and Science, Changde 415000, China
[5] Tata Institute of Fundamental Research, Homi Bhabha Road, Colaba, Mumbai - 400005, India

Received 6 June 2006 / Accepted ??

ABSTRACT

In this paper, we used the database of the university of Michigan Radio Astronomy Observatory (UMRAO) at three (4.8 GHz, 8.0 GHZ, and 14.5 GHz) radio frequency to analyze the radio light curves by the power spectral analysis method in search of possible periodicity. The analysis results showed that the radio sources display astrophysically meaningful periodicity ranging from 2.2 to 20.8 years in their light curves at the three frequencies. We also calculated the variability parameters and investigated the correlations between the variability parameter and the flux density. For the variability parameters, we found that the parameters at higher frequency are higher than those in the lower frequency. In addition, the variability parameters of BL Lacertae objects are larger than those of flat-spectrum radio quasars. suggesting that they are more variable than flat spectrum radio quasars.

Key words. Galaxies: blazars – radio continuum: general-Methods: Data analysis

1. Introduction

The nature of the central engine of blazars and other classes of active galactic nuclei (AGNs) is still an open problem. Blazars' light curves were generated by using the data of their monitoring program, which have yielded very valuable information about the mechanisms operating in these sources and important implications for quasar modeling (Fan et al., 1998). In the past two decades, optical monitoring program of blazars and other classes of AGNs have been conducted extensively by many groups around the globe, and blazars were reported to display flux variability on diverse time scales ranging from a few minutes to hours, to days, to months, and to even more than 10 years (Fan, 2005b). The variability time scale on years gives the long-term variation information in the source and an important tool predicting other outburst times.

Radio monitoring programs were carried out at Bologna at 408 MHz (Bondi et al., 1996), Michigan University at 4.8 GHz, 8 GHz, 14.5 GHz, and Metsähovi observatory at 22 GHz, 37 GHz, 87 GHz, ESO site on Cerro La Silla, Chile, at 90 GHz and 230 GHz (Tornikoski et al., 1996). Using the data of these monitoring, many groups have investigated the variability properties and found that blazars show interesting results. Based on this radio data base, Kraus et al. (1999) report that blazars' emission is strongly beamed, Lahteenmaki & Valtaoja (1999) estimated the radio Doppler factors for a sample of radio sources, Ciaramella et al. (2004) investigated the possible periodicity for several selected objects, and Aller et al. (2003) investigated other variability properties.

In this paper, we make use of the UMRAO data base to investigate the possible periodicity, the variability parameter, and the correlation between the source brightness and the variability parameter. Section 2 presents the details about periodicity analysis method, Sect. 3 variability parameter, Sect. 4, the results of the present work, and in sect. 5 our discussions and conclusions are given.

2. Power spectral (Fourier) periodicity analysis method and results

There are many methods of time series data analysis. The fact that the astronomical observations are generally not evenly sampled will put some constraints on the analysis methods. In this paper, we used the power spectral analysis to search periodicity in the radio light curves of radio sources because it is a powerful and familiar method for detecting a periodic signal, and it gives some quantitative criteria for the detection of a periodic signal.

Many attempts at power spectral analysis have been made for the case that the data are unevenly spaced in time. the *modified periodogram* was widely used by astronomers (Scargle, 1982; Horne & Baliunas, 1986), it is based on a least-square regression onto the two trial functions, $\sin(\omega t)$ and $\cos(\omega t)$. A superior technigue is the *date-compensated discrete Fourier transform*,or DCDFT (Ferraz-Mello, 1981; Foster, 1995), a least-square regression on $\sin(\omega t)$, $\cos(\omega t)$ and constant. The DCDFT is a more powerful method than the *modified periodogram* for unevenly-spaced data, so we adopted it to the R light curve as Foster (1995) describes.

The observed data $x(t_i)$ can define the data vector

$$|x\rangle = [x(t_1), x(t_2), \cdots, x(t_N)]. \quad (1)$$

Send offprint requests to: J. H. Fan, e-mail: fjh@gzhu.edu.cn

First, defining the *inner product* of two funcitons f and g as the average value of the product f^*g over the observation times $\{t_n\}$, we get

$$\langle f|g\rangle = (\frac{1}{N})\sum_{n=1}^{N} f^*(t_n)g(t_n). \tag{2}$$

A subspace are spanned by 3 trial functions $\phi_1(t) = 1$ (constant), $\phi_2(t) = \sin(\omega t)$, and $\phi_3(t) = \cos(\omega t)$. These 3 trial functions define a set of trial vectors,

$$|\phi_\alpha\rangle = [\phi_\alpha(t_1), \phi_\alpha(t_2), \cdots, \phi_\alpha(t_N)],\ \alpha = 1, 2, 3. \tag{3}$$

The data vector $|x\rangle$ can be projected onto the subspace spanned by the $|\phi_\alpha\rangle$ results in a model vector $|y\rangle$ and a residual vector $|\Theta\rangle$,

$$|x\rangle = |y\rangle + |\Theta\rangle\,, \tag{4}$$

The model vector $|y\rangle$ is defined as

$$|y\rangle = \sum_\alpha c_\alpha\,|\phi_\alpha\rangle\,. \tag{5}$$

The c_α can be obtained by taking the inner product of each trial vector ϕ_α with the data vector x, and we have

$$\langle\phi_\alpha|x\rangle = \sum_\beta c_\beta\left\langle\phi_\alpha|\phi_\beta\right\rangle = \sum_\beta S_{\alpha\beta}c_\beta, \tag{6}$$

which defines the S matrix $S_{\alpha\beta}$. Inverting this matrix yields the coefficients,

$$c_\alpha = \sum_\beta S^{-1}_{\alpha\beta}\left\langle\phi_\beta|x\right\rangle, \tag{7}$$

where s^2 is the estimated data variance, and it can be replaced by δ^2. The power level of DCDFT is,

$$P_X(\omega) = \frac{1}{2}N[\langle y|y\rangle - \langle 1|y\rangle^2]/s^2. \tag{8}$$

We adopted the *false alarm probability*, F (Horne & Baliunas, 1986), to give a quantitative criterion for the detection of a periodic signal derived by DCDFT. It was done with the following steps. First, the power level of the periodogram is normalized by the total variance,

$$P_N(\omega) = P_X(\omega)/\delta^2 \tag{9}$$

The probability that $P_N(\omega_0)$ is of height z or higher is $Pr[P_N(\omega_0) > z] = e^{-z}$. Suppose that z is the highest peak in a periodogram that samples N_i independent frequencies. The probability that each independent frequency is smaller than z is $1 - e^{-z}$, so the probability that each frequency is lower than z is $[1 - e^{-z}]^{N_i}$. Thus, the false alarm probability (FAP) can be defined,

$$F = 1 - [1 - e^{-z}]^{N_i} \tag{10}$$

To compute FAP, we need to know N_i, which is not too difficult to obtain by a simple Monte Carlo method. The FAP tells us the probability that a peak of height z will occur, assuming that the data are pure noise. Consequently, the quantity $1 - F$ is the probability that the data contain a signal.

For illustration we present the analysis results in Fig. 1 for the strong sign of periods in 0605-085 at 8GHz, with the theoretical result obtained using two periods, namely a 7.16-year period with an amplitude of 0.582 and a 4.49-year period with an amplitude of 0.168, and Fig. 2 for the weakest sign of periods in 1040+123 at 8GHz.

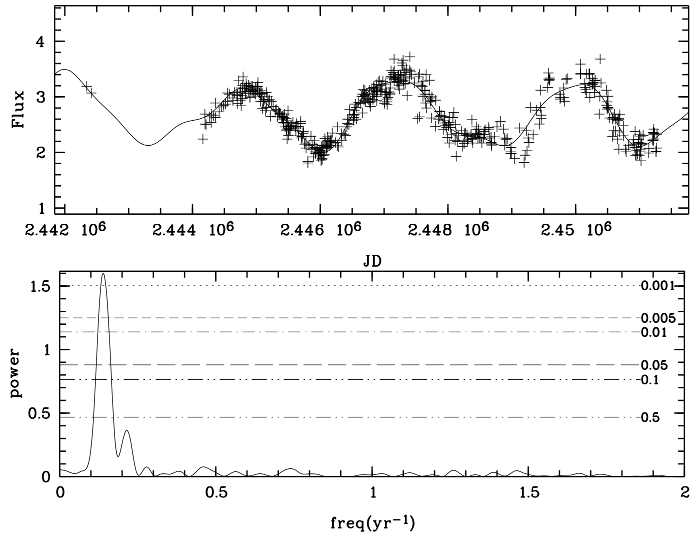

Fig. 1. The strong sign of periods in 0605-085 at 8GHz. The upper panel is for the light curve at 8GHz, while the lower panel is the power spectral analysis result.

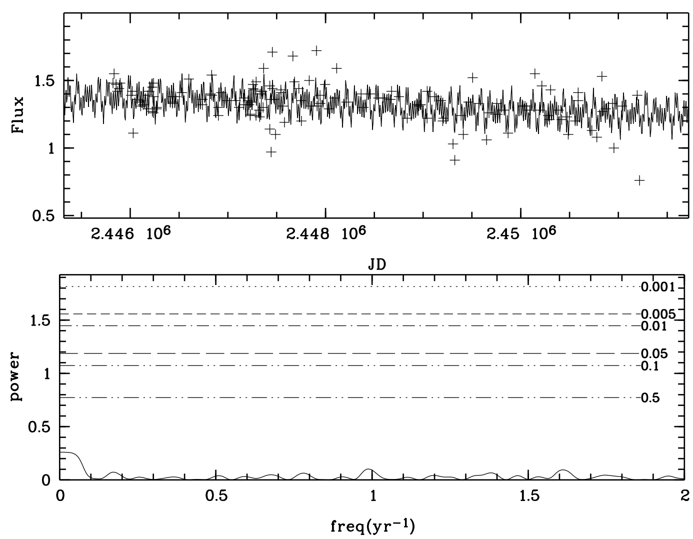

Fig. 2. The weakest sign of periods in 1040+123 at 8GHz. The upper panel is for the light curve at 8GHz, while the lower panel is the power spectral analysis result.

Table 1. Periodicity results and the variability parameters of radio galaxies. Designation indicates the name of the source, Freq the frequency in units of GHz, δ_N the root mean square deviation, the δ_N^2 is the total variance of data; A – the amplitude, FAP – the false alarm probability of the determined possible period, Tms – the determined possible period in units of years, ObT – the time coverage of the light curve in units of years, N – the number of data points, VI – VI index, NVA – NVA index, RMSD – RMSD index, ID – source identification (B for BL Lacertae, Q for the flat spectrum radio quasar and G for galaxy). The superscript "F" means it is not a physically meaningful period ($FAP > 0.5$ or Tms > ObT), and the superscript "P" means it is a possible time scale ($FAP < 0.5$ and $\frac{2}{3}$ObT < Tms < ObT).

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
0003-066	048	0.495	0.650	0.005	17.9 ± 3.1^F	16.7	70				
		0.495	0.648	0.006	9.0 ± 0.8	16.7	70				
		0.495	0.548	0.113	5.3 ± 0.5	16.7	70				
0003-066	080	0.782	1.052	0.001	20.6 ± 2.1^F	19.7	131	0.93	0.31	0.32	B
		0.782	0.919	0.018	9.7 ± 0.9	19.7	131				
		0.782	0.716	0.418	5.7 ± 0.6	19.7	131				
0003-066	145	0.739	0.997	0.002	29.4 ± 5.2^F	17.5	102				
		0.739	0.880	0.020	9.3 ± 1.1	17.5	102				
		0.739	0.687	0.484	7.3 ± 1.2	17.5	102				
		0.739	0.701	0.409	4.9 ± 0.5	17.5	102				
0007+106	048	0.307	0.372	0.015	925.8 ± 9257.1^F	18.5	101				
		0.307	0.363	0.023	10.4 ± 1.3	18.5	101				
		0.307	0.302	0.302	7.2 ± 1.0	18.5	101				
		0.307	0.378	0.011	5.0 ± 0.2	18.5	101				
		0.307	0.298	0.339	3.8 ± 0.3	18.5	101				
		0.307	0.332	0.093	3.2 ± 0.2	18.5	101				
		0.307	0.314	0.197	2.3 ± 0.1	18.5	101				
0007+106	080	0.509	0.450	0.163	64.7 ± 40.8^F	23.1	341	0.90	0.56	0.57	Q
		0.509	0.449	0.165	11.8 ± 1.4	23.1	341				
		0.509	0.494	0.063	7.4 ± 0.4	23.1	341				
		0.509	0.532	0.025	5.2 ± 0.2	23.1	341				
		0.509	0.488	0.072	4.1 ± 0.1	23.1	341				
0007+106	145	0.615	0.546	0.185	5.0 ± 0.3	21.0	301				
		0.615	0.549	0.175	4.1 ± 0.2	21.0	301				
0016+731	048	0.300	0.319	0.044	777.7 ± 8011.9^F	15.6	201				
0016+731	080	0.455	0.475	0.111	81.5 ± 118.3^F	15.2	127	0.93	0.32	0.34	Q
		0.455	0.429	0.337	6.6 ± 1.0	15.2	127				
0016+731	145	0.446	0.408	0.217	32.8 ± 18.3^F	15.5	219				
		0.446	0.455	0.066	6.6 ± 0.6	15.5	219				
0022+638	048	0.292	0.150	1.000	0.1 ± 0.0^F	15.9	68				
0022+638	080	0.368	0.279	1.000	0.1 ± 0.0^F	15.3	48	*	*	*	
0022+638	145	0.160	0.115	1.000	0.3 ± 0.0^F	15.4	59				
0040+517	048	0.126	0.079	1.000	0.2 ± 0.0^F	14.2	54				
0040+517	080	0.182	0.127	1.000	0.1 ± 0.0^F	14.0	40	0.93	0.07	0.18	G
0040+517	145	0.106	0.060	1.000	0.3 ± 0.0^F	14.3	83				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
0048-097	048	0.260	0.166	0.999	33.0 ± 32.3^F	18.5	144				
0048-097	080	0.446	0.408	0.103	125.2 ± 109.4^F	29.1	372	0.92	0.30	0.31	B
0048-097	145	0.459	0.343	0.589	16.8 ± 4.4^F	19.6	304				
0059+581	048	0.339	0.312	0.988	0.5 ± 0.1^F	4.2	27				
0059+581	080	0.281	0.231	1.000	3.4 ± 2.4^F	3.9	35	0.92	0.10	0.20	Q
0059+581	145	0.876	1.125	0.008	3.4 ± 0.4^P	4.8	69				
		0.876	1.101	0.013	1.8 ± 0.1	4.8	69				
0106+013	048	1.121	1.502	0.002	22.2 ± 3.4^F	15.9	105				
0106+013	080	1.134	1.490	0.001	24.4 ± 2.1^F	21.9	284	0.93	0.30	0.30	Q
0106+013	145	1.091	1.410	0.001	26.8 ± 3.0^F	24.4	209				
0108+388	048	0.096	0.057	1.000	0.2 ± 0.0^F	15.5	66				
0108+388	080	0.135	0.060	1.000	0.1 ± 0.0^F	15.0	97	0.86	0.12	0.18	Q
0108+388	145	0.047	0.030	1.000	0.2 ± 0.0^F	15.5	63				
0109+224	048	0.189	0.180	0.432	83.3 ± 138.6^F	18.9	92				
0109+224	080	0.236	0.218	0.412	52.1 ± 45.0^F	20.9	124	0.90	0.37	0.39	B
0109+224	145	0.249	0.243	0.242	37.6 ± 22.6^F	19.6	123				
0127+233	048	0.100	0.059	1.000	0.1 ± 0.0^F	16.7	59				
0127+233	080	0.135	0.062	1.000	0.2 ± 0.0^F	16.6	129	0.73	0.15	0.19	Q
0127+233	145	0.056	0.043	0.999	16.8 ± 10.5^F	16.5	69				
0133+476	048	0.367	0.398	0.010	9.0 ± 0.6	19.2	446				
0133+476	080	0.527	0.513	0.021	124.8 ± 75.0^F	28.0	678	0.94	0.24	0.24	Q
		0.527	0.341	0.455	10.9 ± 1.0	28.0	678				
		0.527	0.377	0.286	5.8 ± 0.3	28.0	678				
0133+476	145	0.574	0.546	0.036	1227.0 ± 9467.1^F	24.5	563				
		0.574	0.517	0.066	10.4 ± 0.8	24.5	563				
0134+329	048	0.225	0.211	0.982	0.3 ± 0.0^F	7.5	25				
0134+329	080	0.166	0.130	0.928	22.4 ± 8.6^F	26.9	121	0.96	0.04	0.10	Q
0134+329	145	0.112	0.073	1.000	0.3 ± 0.0^F	17.8	77				
0153+744	048	0.140	0.155	0.098	37.1 ± 29.1^F	14.2	77				
0153+744	080	0.279	0.274	0.844	0.1 ± 0.0^F	13.7	31	0.88	0.29	0.35	Q
0153+744	145	0.091	0.083	0.685	725.1 ± 15642.3^F	14.5	87				
0202+149	048	0.419	0.461	0.046	12.8 ± 2.3^P	16.5	138				
0202+149	080	0.381	0.353	0.107	12.9 ± 1.8	19.5	328	0.94	0.12	0.13	Q
0202+149	145	0.451	0.437	0.112	13.5 ± 2.2^P	19.1	234				
0212+735	048	0.357	0.483	0.001	26.5 ± 3.2^F	15.5	204				
0212+735	080	0.347	0.370	0.049	24.2 ± 6.9^F	18.1	186	0.90	0.13	0.15	Q
0212+735	145	0.456	0.512	0.014	15.0 ± 2.0^P	18.1	249				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
0215+015	048	0.253	0.216	0.871	15.8 ± 6.6^F	18.1	85				
0215+015	080	0.375	0.334	0.324	15.0 ± 3.3^P	19.6	198	0.96	0.24	0.26	B
		0.375	0.341	0.270	3.4 ± 0.2	19.6	198				
0215+015	145	0.454	0.406	0.436	3.6 ± 0.2	19.6	149				
0218+357	048	0.080	0.066	1.000	4.0 ± 2.3^F	6.4	27				
0218+357	080	0.158	0.153	0.961	336.5 ± 12790.9^F	6.7	22	0.88	0.11	0.25	Q
0218+357	145	0.139	0.113	0.904	6.7 ± 4.1^F	5.0	108				
0219+428	048	0.257	0.315	0.014	33.0 ± 11.6^F	18.8	93				
0219+428	080	0.166	0.170	0.242	1218.4 ± 21110.3^F	24.4	83	0.89	0.17	0.21	B
		0.166	0.172	0.217	29.7 ± 12.3^F	24.4	83				
0219+428	145	0.248	0.308	0.009	26.7 ± 6.4^F	19.6	108				
0220+427	048	0.131	0.085	1.000	0.2 ± 0.0^F	15.7	53				
0220+427	080	0.235	0.268	0.096	1452.5 ± 23780.4^F	29.0	55	0.90	0.12	0.19	G
0220+427	145	0.156	0.159	0.398	811.9 ± 17372.2^F	16.2	55				
0234+285	048	0.825	1.037	0.003	15.0 ± 1.6^P	17.4	190				
0234+285	080	1.275	1.737	0.000	17.9 ± 1.3^F	15.8	217	0.97	0.36	0.37	Q
0234+285	145	1.052	1.333	0.002	19.1 ± 2.5^F	15.8	238				
0235+164	048	0.819	0.566	0.442	10.0 ± 1.3	19.6	544				
0235+164	080	1.128	0.666	0.452	5.7 ± 0.3	24.7	916	0.98	0.51	0.51	B
0235+164	145	1.292	0.804	0.436	5.8 ± 0.3	23.5	802				
0300+470	048	0.477	0.582	0.004	29.6 ± 5.2^F	21.5	232				
0300+470	080	0.454	0.515	0.003	43.9 ± 8.5^F	23.4	587	0.96	0.18	0.19	B
0300+470	145	0.513	0.568	0.008	52.1 ± 16.7^F	20.9	418				
0306+102	048	0.183	0.198	0.140	11.8 ± 2.4	18.3	75				
0306+102	080	0.249	0.217	0.132	52.1 ± 26.4^F	21.0	430	0.83	0.25	0.27	Q
		0.249	0.225	0.096	13.5 ± 1.7	21.0	430				
0306+102	145	0.250	0.236	0.134	12.3 ± 1.8	19.6	247				
0315+416	048	0.107	0.067	1.000	0.2 ± 0.0^F	13.9	49				
0315+416	080	0.171	0.124	1.000	0.2 ± 0.0^F	14.0	53	0.90	0.16	0.22	G
0315+416	145	0.096	0.058	1.000	0.3 ± 0.0^F	12.4	67				
0316+413	048	13.303	18.724	0.000	29.6 ± 0.6^F	21.5	563				
0316+413	080	13.954	19.217	0.000	38.2 ± 0.9^F	32.2	1490	0.97	0.30	0.30	Q
		13.954	6.963	0.423	9.7 ± 0.7	32.2	1490				
0316+413	145	11.392	15.462	0.000	38.0 ± 2.0^F	25.2	761				
0323+022	048	0.077	0.054	1.000	0.1 ± 0.0^F	13.2	43				
0323+022	080	0.071	0.046	1.000	0.1 ± 0.0^F	13.3	72	0.83	0.48	0.72	B
0323+022	145	0.044	0.037	1.000	0.1 ± 0.0^F	11.6	32				
0333+321	048	0.308	0.397	0.001	927.6 ± 4504.4^F	18.6	239				
0333+321	080	0.370	0.407	0.007	52.1 ± 16.1^F	20.8	470	0.96	0.20	0.21	Q
		0.370	0.421	0.004	13.5 ± 1.0	20.8	470				
0333+321	145	0.326	0.386	0.003	13.5 ± 1.1^P	19.3	351				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
0336-019	048	0.296	0.286	0.234	10.0 ± 1.6	18.8	137				
0336-019	080	0.400	0.406	0.021	10.4 ± 0.7	24.5	491	0.94	0.15	0.16	Q
0336-019	145	0.434	0.403	0.081	11.3 ± 1.0	24.6	397				
0355+508	048	2.655	3.698	0.000	925.7 ± 2033.4^F	18.5	180				
0355+508	080	2.981	4.076	0.000	33.5 ± 1.3^F	29.0	666	*	*	*	
0355+508	145	3.327	4.581	0.000	37.9 ± 2.2^F	23.6	465				
0404+768	048	0.097	0.084	0.999	0.1 ± 0.0^F	8.8	34				
0404+768	080	0.181	0.187	0.945	0.1 ± 0.0^F	9.2	14	0.98	0.07	0.29	G
0404+768	145	0.223	0.178	1.000	4.9 ± 2.2^F	9.1	34				
0420-014	048	0.768	0.868	0.005	19.2 ± 2.2^F	19.0	476				
0420-014	080	1.015	0.983	0.014	20.7 ± 2.3^P	21.9	911	0.98	0.23	0.23	Q
0420-014	145	0.982	0.801	0.118	22.4 ± 4.2^F	21.7	677				
0422+004	048	0.336	0.426	0.004	37.6 ± 10.3^F	18.6	146				
		0.336	0.303	0.412	6.6 ± 0.8	18.6	146				
0422+004	080	0.359	0.391	0.009	1022.1 ± 6551.7^F	20.4	468	0.94	0.36	0.37	B
0422+004	145	0.408	0.442	0.015	43.4 ± 16.2^F	17.5	343				
0430+052	048	0.706	0.619	0.109	10.4 ± 1.1	19.1	470				
		0.706	0.655	0.062	4.3 ± 0.2	19.1	470				
0430+052	080	2.401	2.713	0.001	86.0 ± 19.0^F	29.2	1111	0.97	0.53	0.53	Q
		2.401	1.567	0.234	13.6 ± 1.2	29.2	1111				
0430+052	145	1.459	1.392	0.019	1239.3 ± 7850.1^F	24.8	827				
		1.459	1.040	0.221	11.8 ± 1.1	24.8	827				
0440-003	048	0.293	0.385	0.042	8.5 ± 1.6	16.1	14				
0440-003	080	0.292	0.370	0.014	17.9 ± 4.3^F	16.1	57	0.90	0.23	0.27	Q
		0.292	0.362	0.022	8.7 ± 1.1	16.1	57				
		0.292	0.330	0.105	5.4 ± 0.6	16.1	57				
		0.292	0.309	0.262	3.1 ± 0.2	16.1	57				
		0.292	0.300	0.368	2.6 ± 0.2	16.1	57				
		0.292	0.298	0.386	2.2 ± 0.1	16.1	57				
0440-003	145	0.321	0.408	0.034	8.5 ± 1.4	16.3	28				
0454-234	048	0.196	0.248	0.400	2.2 ± 0.3	8.6	9				
0454-234	080	0.304	0.361	0.128	749.2 ± 16092.2^F	15.0	25	0.95	0.17	0.27	Q
0454-234	145	0.386	0.466	0.300	107.1 ± 3025.0^F	2.1	13				
0458-020	048	0.579	0.584	0.333	10.7 ± 4.1^P	10.8	75				
		0.579	0.580	0.354	4.1 ± 0.6	10.8	75				
		0.579	0.562	0.477	2.8 ± 0.3	10.8	75				
0458-020	080	0.790	0.903	0.014	20.5 ± 4.4^F	16.1	212	0.94	0.25	0.26	Q
0458-020	145	0.683	0.784	0.019	405.0 ± 3817.0^F	8.1	161				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
0518+165	048	0.137	0.140	0.036	874.8 ± 7815.4^F	17.5	312				
0518+165	080	0.191	0.181	0.070	24.4 ± 4.7^F	23.9	388	0.94	0.25	0.26	Q
0518+165	145	0.132	0.099	0.347	835.1 ± 10224.4^F	16.7	477				
0521-365	048	0.392	0.346	0.559	920.7 ± 16979.0^F	18.4	127				
0521-365	080	0.510	0.529	0.033	897.4 ± 7929.8^F	17.9	306	0.96	0.08	0.10	Q
0521-365	145	0.731	0.674	0.194	64.0 ± 53.9^F	19.5	228				
0528+134	048	1.005	1.054	0.065	14.2 ± 2.5^P	18.4	173				
		1.005	1.139	0.021	7.2 ± 0.5	18.4	173				
		1.005	1.118	0.028	4.8 ± 0.2	18.4	173				
		1.005	0.892	0.378	3.7 ± 0.2	18.4	173				
0528+134	080	1.749	1.504	0.131	12.9 ± 1.5	23.0	468	0.97	0.40	0.40	Q
		1.749	1.256	0.439	7.4 ± 0.6	23.0	468				
		1.749	1.529	0.113	4.9 ± 0.2	23.0	468				
0528+134	145	2.272	2.323	0.037	16.8 ± 2.7^P	18.6	311				
		2.272	2.577	0.008	8.5 ± 0.5	18.6	311				
		2.272	2.105	0.116	5.6 ± 0.4	18.6	311				
		2.272	2.258	0.053	4.1 ± 0.2	18.6	311				
0528-250	048	0.115	0.070	1.000	1.4 ± 0.1^F	19.2	73				
0528-250	080	0.104	0.086	0.988	6.9 ± 2.7^F	10.5	60	0.81	0.10	0.19	Q
0528-250	145	0.121	0.067	1.000	0.2 ± 0.0^F	17.0	80				
0538+498	048	0.173	0.154	0.568	22.1 ± 12.5^F	14.8	118				
0538+498	080	0.222	0.187	0.665	44.2 ± 26.4^F	28.0	141	0.97	0.04	0.10	Q
0538+498	145	0.221	0.185	0.817	13.5 ± 5.1^F	15.4	108				
0552+398	048	0.285	0.263	0.687	8.0 ± 2.4^F	11.9	75				
0552+398	080	1.127	1.426	0.001	26.9 ± 2.5^P	28.5	274	0.95	0.19	0.20	Q
0552+398	145	1.058	1.220	0.008	20.6 ± 3.2^F	19.1	271				
		1.058	1.208	0.010	14.2 ± 1.6^P	19.1	271				
0605+480	048	0.077	0.046	1.000	2.8 ± 0.5^F	14.5	55				
0605+480	080	0.174	0.111	1.000	0.1 ± 0.0^F	15.9	52	0.75	0.19	0.25	G
0605+480	145	0.056	0.033	1.000	0.1 ± 0.0^F	14.3	51				
0605-085	048	0.349	0.391	0.009	7.3 ± 0.5	16.1	347				
0605-085	080	0.460	0.582	0.001	7.2 ± 0.2	24.5	510	0.91	0.17	0.18	Q
0605-085	145	0.562	0.393	0.472	831.4 ± 10977.6^F	16.6	490				
		0.562	0.705	0.001	7.3 ± 0.3	16.6	490				
0607-157	048	1.233	1.312	0.011	1060.0 ± 7037.1^F	21.2	483				
0607-157	080	2.014	2.275	0.002	123.1 ± 54.6^F	24.3	820	0.97	0.57	0.57	Q
		2.014	1.904	0.022	10.9 ± 0.6	24.3	820				
0607-157	145	2.349	2.625	0.003	1001.6 ± 4829.6^F	20.0	719				
		2.349	2.302	0.018	10.4 ± 0.7	20.0	719				
		2.349	1.524	0.421	6.5 ± 0.5	20.0	719				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
0710+439	048	0.085	0.053	1.000	0.1 ± 0.0^F	13.9	51				
0710+439	080	0.133	0.088	1.000	0.3 ± 0.0^F	21.9	58	0.95	0.10	0.17	Q
0710+439	145	0.055	0.036	1.000	0.2 ± 0.0^F	14.5	62				
0711+356	048	0.127	0.142	0.051	711.0 ± 8723.3^F	14.2	112				
0711+356	080	0.134	0.087	1.000	805.2 ± 24638.6^F	16.1	111	0.80	0.17	0.22	Q
0711+356	145	0.060	0.035	1.000	0.1 ± 0.0^F	14.5	107				
0716+714	048	0.215	0.191	0.283	15.0 ± 3.6^P	17.6	219				
		0.215	0.192	0.275	9.3 ± 1.4	17.6	219				
		0.215	0.187	0.345	7.8 ± 1.0	17.6	219				
		0.215	0.199	0.200	5.7 ± 0.5	17.6	219				
0716+714	080	0.300	0.188	0.987	4.1 ± 0.4^F	17.8	214	0.95	0.31	0.34	B
0716+714	145	0.375	0.337	0.097	16.8 ± 3.0^P	18.1	439				
		0.375	0.324	0.140	9.7 ± 1.1	18.1	439				
		0.375	0.330	0.117	5.4 ± 0.3	18.1	439				
0723+679	048	0.090	0.047	1.000	0.7 ± 0.0^F	13.9	115				
0723+679	080	0.194	0.121	1.000	0.1 ± 0.0^F	17.5	90	0.82	0.24	0.29	Q
0723+679	145	0.111	0.068	1.000	2.6 ± 0.3^F	17.4	115				
0735+178	048	0.834	1.008	0.002	12.9 ± 0.9^P	19.2	362				
0735+178	080	0.923	0.944	0.011	15.0 ± 1.2^P	22.1	679	0.97	0.38	0.39	B
0735+178	145	1.039	1.179	0.003	13.5 ± 0.9	21.6	607				
0754+100	048	0.523	0.542	0.167	15.0 ± 3.6^P	19.2	100				
		0.523	0.538	0.182	11.8 ± 2.3	19.2	100				
		0.523	0.529	0.222	6.6 ± 0.7	19.2	100				
0754+100	080	0.617	0.691	0.014	10.4 ± 0.8	21.1	261	0.95	0.36	0.37	B
0754+100	145	0.605	0.674	0.015	11.3 ± 1.0	20.3	263				
		0.605	0.524	0.278	6.8 ± 0.6	20.3	263				
0804+499	048	0.297	0.251	0.567	5.8 ± 0.8^F	15.3	164				
0804+499	080	0.469	0.322	0.977	1.0 ± 0.0^F	18.8	170	0.87	0.38	0.39	Q
0804+499	145	0.502	0.366	0.930	1.3 ± 0.0^F	18.7	166				
0808+019	048	0.269	0.211	0.990	2.7 ± 0.2^F	19.2	80				
0808+019	080	0.329	0.235	0.998	2.8 ± 0.2^F	19.4	101	0.94	0.30	0.32	B
0808+019	145	0.312	0.212	1.000	4.5 ± 0.6^F	19.5	99				
0809+483	048	0.081	0.064	1.000	0.1 ± 0.0^F	12.4	38				
0809+483	080	0.134	0.073	1.000	0.1 ± 0.0^F	31.4	68	0.96	0.04	0.13	Q
0809+483	145	0.085	0.049	1.000	0.1 ± 0.0^F	14.5	81				
0814+425	048	0.436	0.570	0.002	20.6 ± 2.5^F	19.1	150				
0814+425	080	0.337	0.377	0.007	20.7 ± 2.5^P	21.9	407	0.94	0.18	0.19	B
0814+425	145	0.454	0.548	0.004	19.2 ± 2.1^P	21.7	263				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
0818-128	048	0.238	0.245	0.287	915.4 ± 17161.3^F	18.3	70				
0818-128	080	0.243	0.226	0.512	64.0 ± 81.0^F	19.6	97	0.96	0.26	0.28	B
0818-128	145	0.268	0.250	0.491	8.8 ± 1.6	18.1	99				
0829+046	048	0.295	0.279	0.495	15.0 ± 4.7^P	18.6	90				
0829+046	080	0.445	0.486	0.033	15.9 ± 2.4^P	21.0	187	0.94	0.31	0.32	B
0829+046	145	0.498	0.476	0.231	16.8 ± 4.2^P	19.6	153				
0831+557	048	0.159	0.115	1.000	0.4 ± 0.0^F	13.6	45				
0831+557	080	0.193	0.132	1.000	0.1 ± 0.0^F	24.8	61	0.95	0.05	0.14	G
0831+557	145	0.162	0.108	1.000	0.2 ± 0.0^F	14.3	50				
0836+710	048	0.207	0.145	0.964	839.4 ± 18773.4^F	16.8	171				
0836+710	080	0.429	0.451	0.121	838.0 ± 11917.1^F	16.8	111	0.97	0.20	0.23	Q
		0.429	0.399	0.444	8.2 ± 1.5	16.8	111				
0836+710	145	0.428	0.384	0.257	840.5 ± 11460.5^F	16.8	221				
		0.428	0.444	0.053	9.0 ± 1.0	16.8	221				
		0.428	0.380	0.282	5.7 ± 0.5	16.8	221				
0838+133	048	0.092	0.072	0.985	7.7 ± 2.3^F	13.9	86				
0838+133	080	0.147	0.106	0.990	7.8 ± 1.5^F	20.8	121	0.89	0.10	0.15	Q
0838+133	145	0.180	0.120	1.000	1.8 ± 0.2^F	12.5	49				
0850+581	048	0.066	0.073	0.152	114.4 ± 338.7^F	13.9	54				
0850+581	080	0.164	0.107	1.000	0.1 ± 0.0^F	13.6	47	0.88	0.15	0.22	Q
0850+581	145	0.077	0.052	1.000	725.3 ± 25955.0^F	14.5	72				
0851+202	048	0.904	1.028	0.003	26.7 ± 3.5^F	20.1	604				
		0.904	0.608	0.445	8.8 ± 1.0	20.1	604				
0851+202	080	1.363	1.158	0.049	1411.3 ± 10062.4^F	28.2	966	0.97	0.37	0.37	B
		1.363	1.199	0.036	18.0 ± 1.6	28.2	966				
		1.363	0.901	0.266	9.4 ± 0.6	28.2	966				
0851+202	145	1.728	1.964	0.002	22.4 ± 1.8^P	24.7	815				
0859+470	048	0.159	0.136	0.971	14.1 ± 7.8^F	15.0	56				
0859+470	080	0.150	0.112	1.000	11.3 ± 5.0^F	16.3	70	0.81	0.12	0.18	Q
0859+470	145	0.117	0.094	0.994	736.8 ± 22479.3^F	14.7	61				
0906+430	048	0.107	0.097	0.359	933.4 ± 14570.3^F	18.7	166				
0906+430	080	0.222	0.245	0.025	983.7 ± 9249.3^F	19.7	200	0.92	0.15	0.17	Q
		0.222	0.199	0.289	14.2 ± 2.9^P	19.7	200				
0906+430	145	0.216	0.267	0.005	947.4 ± 6651.9^F	18.9	174				
0912+297	048	0.059	0.047	0.997	0.1 ± 0.0^F	18.4	63				
0912+297	080	0.103	0.052	1.000	1.3 ± 0.1^F	18.9	83	0.81	0.34	0.44	B
0912+297	145	0.053	0.037	1.000	902.7 ± 29308.9^F	18.1	79				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
0917+458	048	0.131	0.091	1.000	0.3 ± 0.0^F	14.2	54				
0917+458	080	0.130	0.095	1.000	0.1 ± 0.0^F	15.9	60	0.90	0.08	0.16	Q
0917+458	145	0.088	0.091	0.333	714.7 ± 14496.6^F	14.3	59				
0923+392	048	1.870	2.616	0.000	24.3 ± 0.6^F	21.0	476				
0923+392	080	2.880	3.782	0.000	22.5 ± 0.7^P	31.9	1008	0.95	0.32	0.32	Q
0923+392	145	3.166	4.398	0.000	24.4 ± 0.6^P	25.0	656				
0951+699	048	0.096	0.059	1.000	0.1 ± 0.0^F	13.2	45				
0951+699	080	0.306	0.219	1.000	0.3 ± 0.0^F	15.9	38	0.88	0.12	0.20	G
0951+699	145	0.132	0.085	1.000	1.0 ± 0.1^F	14.0	53				
0954+556	048	0.077	0.038	1.000	0.1 ± 0.0^F	18.7	86				
0954+556	080	0.131	0.063	1.000	0.3 ± 0.0^F	24.8	111	0.88	0.06	0.12	Q
0954+556	145	0.099	0.048	1.000	0.2 ± 0.0^F	18.7	97				
0954+658	048	0.321	0.376	0.016	19.1 ± 4.7^F	14.6	141				
0954+658	080	0.431	0.467	0.070	20.5 ± 7.6^F	14.0	122	0.96	0.46	0.48	B
0954+658	145	0.266	0.311	0.012	588.3 ± 4944.7^F	11.8	183				
0957+227	048	0.062	0.035	1.000	0.1 ± 0.0^F	18.4	62				
0957+227	080	0.081	0.038	1.000	0.1 ± 0.0^F	19.2	78	0.77	0.20	0.31	B
0957+227	145	0.052	0.036	1.000	0.1 ± 0.0^F	19.5	79				
1003+351	048	0.090	0.053	1.000	0.2 ± 0.0^F	14.2	53				
1003+351	080	0.131	0.099	1.000	22.2 ± 23.1^F	15.8	51	0.75	0.10	0.19	Q
1003+351	145	0.067	0.048	1.000	0.1 ± 0.0^F	12.8	48				
1031+567	048	0.080	0.057	1.000	0.4 ± 0.0^F	13.7	57				
1031+567	080	0.150	0.101	1.000	2.6 ± 0.3^F	18.4	53	0.76	0.16	0.23	G
1031+567	145	0.075	0.056	1.000	0.3 ± 0.0^F	14.3	51				
1034-293	048	0.328	0.218	1.000	9.4 ± 3.2^F	19.2	79				
1034-293	080	0.353	0.208	1.000	9.4 ± 3.0^F	21.1	101	0.87	0.20	0.22	Q
1034-293	145	0.483	0.359	0.999	9.0 ± 2.6^F	18.5	83				
1038+528	048	0.133	0.123	0.850	14.0 ± 10.2^F	10.5	49				
1038+528	080	0.233	0.202	0.992	537.9 ± 18005.6^F	10.8	41	0.93	0.28	0.33	Q
1038+528	145	0.251	0.314	0.022	9.3 ± 2.0^P	10.8	51				
1040+123	048	0.079	0.046	1.000	12.8 ± 9.3^F	13.9	90				
1040+123	080	0.140	0.071	1.000	738.8 ± 26306.2^F	14.8	146	0.85	0.09	0.13	Q
1040+123	145	0.068	0.058	0.732	24.0 ± 18.2^F	13.0	114				
1055+018	048	0.250	0.208	0.515	2.6 ± 0.1^F	16.5	200				
1055+018	080	0.476	0.454	0.041	26.9 ± 3.6^P	32.2	513	0.97	0.13	0.14	Q
1055+018	145	0.718	0.670	0.073	22.4 ± 4.3^F	21.7	413				
		0.718	0.560	0.329	5.0 ± 0.3	21.7	413				
1100+772	048	0.082	0.045	1.000	0.1 ± 0.0^F	14.2	69				
1100+772	080	0.210	0.176	0.997	10.8 ± 4.9^F	15.9	46	0.80	0.33	0.41	B
1100+772	145	0.075	0.059	1.000	0.1 ± 0.0^F	3.0	14				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
1101+384	048	0.102	0.049	1.000	3.7 ± 0.5^F	18.4	244				
1101+384	080	0.127	0.068	0.958	8.0 ± 1.2^F	21.0	416	0.87	0.16	0.19	B
1101+384	145	0.092	0.052	0.973	5.4 ± 0.6^F	20.0	335				
1127-145	048	0.296	0.279	0.091	32.9 ± 12.9^F	17.3	325				
		0.296	0.277	0.098	8.7 ± 0.9	17.3	325				
1127-145	080	0.515	0.591	0.001	1565.8 ± 6122.6^F	31.3	944	0.96	0.14	0.15	Q
1127-145	145	0.289	0.204	0.377	3.4 ± 0.1	24.2	577				
1133+704	048	0.066	0.037	1.000	1.3 ± 0.1^F	12.2	86				
1133+704	080	0.106	0.062	1.000	0.1 ± 0.0^F	18.9	89	0.30	0.20	0.40	B
1133+704	145	0.090	0.059	1.000	0.1 ± 0.0^F	18.1	67				
1137+660	048	0.108	0.067	1.000	0.3 ± 0.0^F	17.9	62				
1137+660	080	0.221	0.116	1.000	8.5 ± 3.1^F	18.2	116	0.96	0.25	0.29	Q
1137+660	145	0.071	0.056	1.000	10.0 ± 4.1^F	18.2	46				
1147+245	048	0.101	0.070	1.000	17.9 ± 12.2^F	18.4	72				
1147+245	080	0.130	0.101	0.942	20.6 ± 10.2^F	19.6	116	0.89	0.15	0.19	B
1147+245	145	0.091	0.084	0.530	24.3 ± 11.8^F	19.6	98				
1148-001	048	0.144	0.193	0.005	20.3 ± 9.9^F	11.1	19				
1148-001	080	0.108	0.116	0.144	63.0 ± 80.5^F	15.6	82	0.81	0.05	0.13	Q
1148-001	145	0.125	0.156	0.050	7.9 ± 1.9^P	11.3	26				
1156+295	048	0.296	0.206	0.766	8.0 ± 1.2^F	17.9	293				
1156+295	080	0.404	0.272	0.416	10.4 ± 1.2	21.9	639	0.97	0.23	0.24	Q
		0.404	0.326	0.141	3.3 ± 0.1	21.9	639				
		0.404	0.291	0.297	2.7 ± 0.1	21.9	639				
1156+295	145	0.595	0.433	0.368	3.4 ± 0.1	18.9	513				
		0.595	0.408	0.492	2.7 ± 0.1	18.9	513				
1157+732	048	0.111	0.077	1.000	0.1 ± 0.0^F	14.2	61				
1157+732	080	0.227	0.165	1.000	0.2 ± 0.0^F	14.0	37	0.92	0.12	0.21	G
1157+732	145	0.086	0.065	1.000	0.2 ± 0.0^F	14.3	50				
1215+303	048	0.071	0.046	1.000	11.3 ± 3.8^F	19.2	123				
1215+303	080	0.107	0.061	1.000	0.1 ± 0.0^F	19.6	101	0.68	0.18	0.24	B
1215+303	145	0.079	0.061	0.983	7.0 ± 1.3^F	19.6	94				
1217+023	048	0.043	0.041	1.000	0.3 ± 0.8^F	0.1	6				
1217+023	080	0.099	0.100	1.000	0.1 ± 0.1^F	0.1	5	0.63	0.15	0.53	Q
1217+023	145	0.055	0.054	1.000	17.4 ± 827.9^F	0.4	13				
1219+285	048	0.462	0.604	0.002	933.4 ± 4984.1^F	18.7	165				
1219+285	080	0.557	0.740	0.001	33.1 ± 4.0^F	20.3	276	0.86	0.39	0.40	B
		0.557	0.476	0.293	10.4 ± 1.4	20.3	276				
1219+285	145	0.566	0.759	0.001	37.7 ± 5.5^F	20.4	203				
		0.566	0.505	0.306	10.0 ± 1.4	20.4	203				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
1222+216	048	0.201	0.220	0.914	2.4 ± 3.4^F	1.3	12				
1222+216	080	0.248	0.279	0.261	2.7 ± 1.6^F	2.2	28	0.96	0.11	0.22	Q
1222+216	145	0.345	0.411	0.046	2.6 ± 0.5^P	3.5	57				
1225+206	048	0.088	0.052	1.000	0.2 ± 0.0^F	17.8	55				
1225+206	080	0.090	0.052	1.000	0.2 ± 0.0^F	19.6	88	0.55	0.23	0.32	Q
1225+206	145	0.034	0.020	1.000	64.0 ± 170.7^F	19.6	78				
1226+023	048	3.004	3.623	0.001	8.8 ± 0.3	21.0	493				
1226+023	080	5.603	3.982	0.118	53.1 ± 13.3^F	33.8	1294	0.97	0.14	0.15	Q
		5.603	4.060	0.104	19.3 ± 1.7	33.8	1294				
		5.603	5.591	0.006	8.3 ± 0.2	33.8	1294				
1226+023	145	7.863	9.638	0.001	8.2 ± 0.2	25.0	760				
1253-055	048	1.631	1.789	0.006	1051.2 ± 6065.5^F	21.0	551				
1253-055	080	3.690	4.248	0.001	1684.3 ± 5795.8^F	33.7	1194	0.95	0.27	0.27	Q
		3.690	2.134	0.352	15.1 ± 1.5	33.7	1194				
		3.690	2.014	0.426	10.1 ± 0.7	33.7	1194				
		3.690	2.213	0.307	7.4 ± 0.3	33.7	1194				
		3.690	2.126	0.357	5.1 ± 0.2	33.7	1194				
1253-055	145	5.683	7.513	0.000	1248.4 ± 2834.4^F	25.0	779				
1254+476	048	0.074	0.052	1.000	0.2 ± 0.0^F	14.2	57				
1254+476	080	0.153	0.109	1.000	0.3 ± 0.0^F	14.0	60	0.89	0.13	0.19	G
1254+476	145	0.041	0.027	1.000	700.7 ± 29886.7^F	14.0	57				
1307+121	048	0.168	0.213	0.016	22.3 ± 6.1^F	18.4	55				
1307+121	080	0.245	0.309	0.007	22.3 ± 4.0^F	20.7	102	0.88	0.22	0.25	B
1307+121	145	0.232	0.306	0.002	20.6 ± 2.6^F	19.6	108				
1308+326	048	0.762	0.826	0.008	19.2 ± 2.2^P	20.7	523				
		0.762	0.718	0.045	11.8 ± 1.1	20.7	523				
1308+326	080	0.772	0.587	0.115	22.4 ± 3.7^P	22.8	975	0.93	0.29	0.29	B
		0.772	0.569	0.143	9.7 ± 0.7	22.8	975				
		0.772	0.439	0.476	5.9 ± 0.4	22.8	975				
1308+326	145	0.799	0.744	0.028	8.5 ± 0.4	22.7	782				
1328+307	048	0.078	0.021	1.000	8.2 ± 2.5^F	19.2	571				
1328+307	080	0.102	0.074	0.223	33.4 ± 8.4^F	26.9	741	0.94	0.01	0.04	Q
1328+307	145	0.091	0.034	0.813	10.4 ± 1.5^F	24.5	1273				
1335-127	048	0.823	0.922	0.009	8.0 ± 0.5	19.2	348				
1335-127	080	1.208	1.186	0.017	8.2 ± 0.4	24.6	723	0.98	0.26	0.26	Q
		1.208	0.878	0.238	5.7 ± 0.3	24.6	723				
1335-127	145	1.461	1.477	0.020	8.0 ± 0.4	23.6	516				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
1354-152	048	0.122	0.158	0.556	0.1 ± 0.0^F	5.6	6				
1354-152	080	0.578	0.735	0.016	19.1 ± 5.3^F	15.9	49	0.97	0.32	0.35	Q
1354-152	145	0.532	0.724	0.010	5.7 ± 0.5	13.8	21				
1358+624	048	0.077	0.040	1.000	814.5 ± 27901.1^F	16.3	153				
1358+624	080	0.129	0.059	1.000	0.1 ± 0.0^F	19.2	158	0.96	0.09	0.13	G
1358+624	145	0.054	0.023	1.000	0.3 ± 0.0^F	16.5	136				
1400+162	048	0.069	0.042	1.000	1.0 ± 0.0^F	18.7	68				
1400+162	080	0.088	0.048	1.000	0.1 ± 0.0^F	19.5	96	0.78	0.19	0.27	B
1400+162	145	0.045	0.026	1.000	0.7 ± 0.0^F	20.4	94				
1409+524	048	0.196	0.122	1.000	0.1 ± 0.0^F	14.2	50				
1409+524	080	0.144	0.085	1.000	0.2 ± 0.0^F	14.0	52	0.95	0.03	0.15	G
1409+524	145	0.099	0.069	1.000	713.8 ± 26000.2^F	14.3	67				
1413+135	048	0.174	0.148	0.351	929.6 ± 13084.3^F	18.6	250				
		0.174	0.164	0.143	8.2 ± 0.9	18.6	250				
1413+135	080	0.377	0.377	0.016	8.2 ± 0.4	21.0	666	0.95	0.25	0.25	B
		0.377	0.272	0.281	4.8 ± 0.2	21.0	666				
1413+135	145	0.672	0.625	0.053	9.4 ± 0.8	18.8	521				
1418+546	048	0.395	0.392	0.049	961.1 ± 8879.8^F	19.2	334				
		0.395	0.318	0.349	9.4 ± 1.2	19.2	334				
1418+546	080	0.541	0.459	0.110	1032.1 ± 9566.1^F	20.6	577	0.92	0.29	0.30	B
		0.541	0.389	0.341	11.3 ± 1.4	20.6	577				
		0.541	0.419	0.218	2.5 ± 0.1	20.6	577				
1418+546	145	0.589	0.570	0.034	997.0 ± 7750.7^F	19.9	520				
1458+718	048	0.156	0.131	0.981	711.0 ± 20868.1^F	14.2	59				
1458+718	080	0.396	0.443	0.173	12.9 ± 2.4	26.9	44	0.95	0.16	0.22	Q
1458+718	145	0.428	0.532	0.025	16.7 ± 5.0^F	14.3	51				
		0.428	0.456	0.275	0.2 ± 0.0	14.3	51				
1504-166	048	0.313	0.393	0.012	29.2 ± 11.6^F	14.6	76				
1504-166	080	0.330	0.396	0.008	20.7 ± 3.1^P	21.7	170	0.97	0.11	0.14	Q
1504-166	145	0.325	0.382	0.026	19.1 ± 5.0^F	16.4	99				
1510-089	048	0.683	0.622	0.084	12.9 ± 1.6	20.1	437				
1510-089	080	0.816	0.596	0.177	12.3 ± 1.2	24.6	874	0.93	0.30	0.31	Q
1510-089	145	1.035	0.948	0.042	12.9 ± 1.0	24.7	671				
1514+197	048	0.169	0.161	0.519	22.3 ± 10.9^F	18.7	79				
1514+197	080	0.206	0.213	0.161	20.7 ± 6.2^P	20.8	104	0.76	0.37	0.40	B
1514+197	145	0.212	0.240	0.067	24.3 ± 8.6^F	19.0	82				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
1538+149	048	0.252	0.284	0.050	29.5 ± 11.7^F	18.5	103				
1538+149	080	0.334	0.343	0.030	22.4 ± 3.9^F	21.6	361	0.96	0.22	0.23	B
		0.334	0.322	0.064	10.4 ± 1.0	21.6	361				
1538+149	145	0.406	0.443	0.021	22.3 ± 4.4^F	19.6	254				
		0.406	0.363	0.225	9.4 ± 1.1	19.6	254				
1543+005	048	0.201	0.235	0.080	20.5 ± 9.2^F	15.0	48				
1543+005	080	0.194	0.206	0.198	20.6 ± 7.3^F	20.4	72	*	*	*	
1543+005	145	0.108	0.130	0.032	17.8 ± 5.3^F	15.4	65				
1606+106	048	0.202	0.194	0.639	600.8 ± 14020.7^F	12.0	60				
1606+106	080	0.443	0.450	0.154	10.4 ± 1.4	21.7	126	0.97	0.26	0.28	Q
1606+106	145	0.284	0.208	1.000	1.0 ± 0.0^F	14.3	74				
1609+660	048	0.090	0.057	1.000	0.1 ± 0.0^F	14.5	64				
1609+660	080	0.215	0.177	1.000	3.0 ± 0.5^F	14.0	42	0.83	0.15	0.23	G
1609+660	145	0.054	0.035	1.000	0.1 ± 0.0^F	14.0	61				
1611+343	048	0.623	0.860	0.000	821.6 ± 2366.7^F	16.4	160				
1611+343	080	0.939	1.297	0.000	43.6 ± 4.3^F	19.5	269	0.96	0.32	0.32	Q
1611+343	145	0.942	1.273	0.000	29.3 ± 3.6^F	16.4	227				
1624+416	048	0.150	0.180	0.040	37.1 ± 26.6^F	14.2	58				
1624+416	080	0.168	0.138	0.996	700.1 ± 22265.9^F	14.0	54	0.81	0.15	0.21	Q
1624+416	145	0.120	0.137	0.108	16.7 ± 6.8^F	14.0	53				
1633+382	048	0.387	0.480	0.003	17.9 ± 2.3^F	16.6	230				
1633+382	080	0.624	0.621	0.036	14.3 ± 1.4	24.8	405	0.95	0.24	0.25	Q
1633+382	145	0.570	0.648	0.009	64.8 ± 24.8^F	24.3	296				
1634+628	048	0.082	0.050	1.000	1.9 ± 0.2^F	14.5	63				
1634+628	080	0.183	0.126	1.000	0.1 ± 0.0^F	13.6	48	0.81	0.19	0.26	Q
1634+628	145	0.049	0.032	1.000	0.1 ± 0.0^F	13.9	55				
1637+574	048	0.244	0.253	0.304	115.8 ± 353.1^F	15.0	61				
1637+574	080	0.362	0.318	0.901	5.9 ± 1.2^F	15.2	64	0.94	0.23	0.27	Q
1637+574	145	0.403	0.356	0.783	3.9 ± 0.5^F	15.1	83				
1641+399	048	1.971	2.410	0.001	18.0 ± 1.1^P	20.9	708				
1641+399	080	2.666	2.610	0.007	20.8 ± 1.2	33.7	1281	0.96	0.26	0.26	Q
		2.666	2.630	0.007	11.3 ± 0.4	33.7	1281				
1641+399	145	2.960	2.793	0.026	20.7 ± 2.3^P	25.0	752				
		2.960	2.651	0.044	10.9 ± 0.7	25.0	752				
1642+690	048	0.197	0.190	0.207	6.6 ± 0.7	18.3	155				
1642+690	080	0.397	0.398	0.056	992.2 ± 9748.6^F	19.8	284	0.88	0.25	0.26	Q
		0.397	0.347	0.235	7.0 ± 0.6	19.8	284				
1642+690	145	0.317	0.260	0.382	922.4 ± 12904.2^F	18.4	279				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
1652+398	048	0.150	0.158	0.052	933.4 ± 9878.5^F	18.7	202				
		0.150	0.155	0.065	11.8 ± 1.6	18.7	202				
1652+398	080	0.186	0.199	0.012	1064.2 ± 7297.2^F	21.3	440	0.98	0.13	0.15	B
		0.186	0.181	0.040	12.3 ± 1.2	21.3	440				
		0.186	0.146	0.288	7.4 ± 0.6	21.3	440				
1652+398	145	0.151	0.169	0.015	1001.3 ± 8145.9^F	20.0	253				
		0.151	0.158	0.038	11.8 ± 1.3	20.0	253				
		0.151	0.133	0.256	6.8 ± 0.6	20.0	253				
1717+178	048	0.188	0.163	0.897	7.0 ± 1.3^F	18.7	73				
1717+178	080	0.209	0.201	0.296	6.8 ± 0.7	21.6	119	0.92	0.27	0.30	B
1717+178	145	0.195	0.199	0.237	7.0 ± 0.9	17.9	89				
1721+343	048	0.058	0.038	1.000	0.2 ± 0.0^F	10.7	49				
1721+343	080	0.122	0.084	1.000	3.4 ± 0.9^F	10.3	52	0.74	0.22	0.28	Q
1721+343	145	0.051	0.039	1.000	0.1 ± 0.0^F	11.0	49				
1727+502	048	0.068	0.037	1.000	0.1 ± 0.0^F	18.7	75				
1727+502	080	0.094	0.043	1.000	982.4 ± 45349.6^F	19.6	109	0.87	0.31	0.47	B
1727+502	145	0.037	0.020	1.000	0.3 ± 0.0^F	19.4	85				
1730-130	048	1.047	0.839	0.413	10.1 ± 1.4	21.0	295				
		1.047	0.955	0.148	6.3 ± 0.4	21.0	295				
		1.047	0.869	0.326	5.0 ± 0.3	21.0	295				
1730-130	080	1.903	1.782	0.028	53.0 ± 12.1^F	32.0	748	0.96	0.31	0.31	Q
		1.903	1.444	0.172	10.1 ± 0.6	32.0	748				
		1.903	1.604	0.078	6.3 ± 0.2	32.0	748				
1730-130	145	2.470	1.876	0.311	33.3 ± 10.9^F	24.2	486				
		2.470	1.804	0.388	10.1 ± 1.0	24.2	486				
		2.470	1.993	0.208	6.1 ± 0.3	24.2	486				
1741-038	048	0.890	1.179	0.002	549.9 ± 3239.2^F	11.0	112				
		0.890	1.088	0.011	8.2 ± 1.1^P	11.0	112				
1741-038	080	1.139	1.437	0.004	1209.3 ± 8200.4^F	24.2	155	0.96	0.29	0.30	Q
		1.139	1.478	0.002	18.0 ± 1.6^P	24.2	155				
		1.139	1.124	0.166	6.5 ± 0.5	24.2	155				
1741-038	145	1.263	1.413	0.018	14.1 ± 3.0^F	11.6	219				
		1.263	1.324	0.047	5.8 ± 0.6	11.6	219				
1749+096	048	0.582	0.425	0.377	10.4 ± 1.4	19.2	500				
		0.582	0.440	0.308	6.3 ± 0.5	19.2	500				
1749+096	080	0.970	0.640	0.309	9.0 ± 0.9	19.8	866	0.96	0.38	0.38	B
		0.970	0.738	0.137	6.8 ± 0.4	19.8	866				
1749+096	145	1.413	0.861	0.536	3.1 ± 0.1^F	20.4	713				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
1749+701	048	0.281	0.323	0.015	29.5 ± 8.0^F	18.7	193				
1749+701	080	0.335	0.365	0.018	22.3 ± 4.2^F	19.2	292	0.67	0.33	0.35	B
		0.335	0.330	0.067	12.3 ± 1.6	19.2	292				
1749+701	145	0.232	0.249	0.029	950.8 ± 8743.0^F	19.0	243				
1803+784	048	0.342	0.298	0.329	11.3 ± 2.0	18.1	220				
		0.342	0.289	0.418	7.8 ± 1.0	18.1	220				
1803+784	080	0.409	0.236	0.997	1.4 ± 0.1^F	18.0	233	0.97	0.13	0.15	B
1803+784	145	0.411	0.369	0.121	7.0 ± 0.6	18.1	381				
1807+698	048	0.145	0.143	0.119	933.5 ± 11424.7^F	18.7	196				
1807+698	080	0.192	0.128	0.702	991.5 ± 15563.9^F	19.8	394	0.95	0.08	0.11	B
1807+698	145	0.189	0.125	0.879	977.5 ± 18228.0^F	19.6	285				
1817-162	048	7.220	5.588	1.000	0.1 ± 0.2^F	0.2	6				
1817-162	080	4.672	5.629	0.230	0.2 ± 0.1^P	0.2	14	*	*	*	
1817-162	145	27.765	30.727	1.000	0.1 ± 0.1^F	0.2	7				
1823+568	048	0.169	0.181	0.107	14.9 ± 4.0^P	15.9	101				
1823+568	080	0.280	0.252	0.270	24.2 ± 9.5^F	17.1	209	0.91	0.19	0.21	B
1823+568	145	0.400	0.445	0.016	19.1 ± 3.4^F	17.7	253				
		0.400	0.361	0.204	8.8 ± 1.1	17.7	253				
1828+487	048	0.332	0.392	0.042	14.1 ± 3.7^P	14.5	68				
1828+487	080	0.390	0.398	0.296	22.5 ± 6.1^P	30.7	75	0.96	0.08	0.14	Q
		0.390	0.426	0.125	10.9 ± 1.2	30.7	75				
1828+487	145	0.466	0.487	0.130	10.4 ± 1.3	24.6	112				
1842+455	048	0.090	0.063	1.000	0.1 ± 0.0^F	14.5	54				
1842+455	080	0.127	0.077	1.000	0.2 ± 0.0^F	13.8	50	0.94	0.09	0.18	G
1842+455	145	0.059	0.036	1.000	0.3 ± 0.0^F	14.3	62				
1845+797	048	0.177	0.168	0.596	7.3 ± 1.6^F	14.7	71				
1845+797	080	0.359	0.328	0.645	10.4 ± 2.1^F	21.6	87	0.91	0.12	0.16	G
1845+797	145	0.250	0.211	0.707	8.2 ± 1.2^F	21.6	130				
1901+319	048	0.264	0.308	0.016	15.8 ± 2.8^P	16.4	157				
1901+319	080	0.232	0.242	0.041	20.7 ± 3.4^P	24.8	242	0.88	0.12	0.15	Q
1901+319	145	0.169	0.131	0.851	4.1 ± 0.4^F	16.5	159				
1921-293	048	2.977	3.485	0.005	22.3 ± 3.1^F	19.9	332				
1921-293	080	3.510	3.478	0.017	52.5 ± 14.6^F	24.6	677	0.97	0.30	0.30	Q
1921-293	145	4.213	3.750	0.069	22.4 ± 3.7^P	23.3	585				
1928+738	048	0.326	0.399	0.004	116.6 ± 110.1^F	15.7	233				
1928+738	080	0.470	0.555	0.009	29.5 ± 7.5^F	18.1	197	0.96	0.13	0.15	Q
		0.470	0.402	0.437	8.2 ± 1.2	18.1	197				
1928+738	145	0.519	0.579	0.009	62.9 ± 35.7^F	15.5	349				
		0.519	0.421	0.313	7.7 ± 1.0	15.5	349				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
1939+605	048	0.066	0.044	1.000	0.3 ± 0.0^{F}	13.9	55				
1939+605	080	0.142	0.101	1.000	13.4 ± 10.5^{F}	13.7	51	0.94	0.13	0.21	G
1939+605	145	0.041	0.026	1.000	0.1 ± 0.0^{F}	14.3	63				
1951+498	048	0.056	0.037	1.000	0.1 ± 0.0^{F}	11.0	47				
1951+498	080	0.131	0.083	1.000	5.5 ± 2.5^{F}	11.1	52	0.71	0.48	0.58	Q
1951+498	145	0.044	0.028	1.000	0.3 ± 0.0^{F}	11.0	45				
1954+513	048	0.187	0.168	0.883	747.0 ± 19864.3^{F}	15.0	58				
1954+513	080	0.338	0.393	0.052	20.6 ± 6.2^{F}	19.0	71	0.92	0.21	0.24	Q
1954+513	145	0.295	0.336	0.084	22.3 ± 8.2^{F}	18.8	62				
2005+403	048	0.719	0.960	0.001	26.6 ± 2.9^{F}	18.4	242				
2005+403	080	0.921	1.055	0.003	1171.4 ± 6187.4^{F}	23.4	522	0.98	0.21	0.22	Q
2005+403	145	0.721	0.915	0.001	1188.3 ± 4289.8^{F}	23.8	517				
2007+777	048	0.409	0.332	0.622	3.7 ± 0.3^{F}	16.0	186				
2007+777	080	0.432	0.358	0.407	2.9 ± 0.1	17.9	252	0.95	0.23	0.24	B
2007+777	145	0.649	0.621	0.058	12.8 ± 1.8^{P}	16.7	395				
2014+370	048	0.474	0.598	0.023	11.2 ± 2.9^{F}	11.0	44				
2014+370	080	0.135	0.083	1.000	0.4 ± 0.0^{F}	15.3	56	*	*	*	
2014+370	145	0.085	0.056	1.000	768.4 ± 30371.9^{F}	15.4	64				
2020+614	048	0.178	0.230	0.009	723.6 ± 7065.9^{F}	14.5	56				
2020+614	080	0.433	0.556	0.012	52.5 ± 23.6^{F}	24.7	52	0.93	0.14	0.20	G
2020+614	145	0.385	0.464	0.032	714.0 ± 9166.0^{F}	14.3	63				
2032+107	048	0.149	0.095	1.000	12.9 ± 7.7^{F}	18.4	59				
2032+107	080	0.211	0.143	1.000	0.2 ± 0.0^{F}	20.5	97	0.91	0.30	0.33	B
2032+107	145	0.222	0.142	1.000	0.1 ± 0.0^{F}	17.1	68				
2037+421	048	0.604	0.544	1.000	0.1 ± 0.1^{F}	0.2	9				
2037+421	080	0.315	0.239	1.000	0.1 ± 0.1^{F}	0.2	12	*	*	*	
2037+421	145	0.399	0.320	1.000	0.1 ± 0.0^{F}	0.3	15				
2121+053	048	1.166	1.224	0.060	6.8 ± 0.6	18.5	185				
2121+053	080	1.337	1.520	0.003	6.8 ± 0.2	22.8	590	0.97	0.48	0.48	Q
2121+053	145	1.071	1.129	0.021	7.0 ± 0.4	20.1	349				
		1.071	0.907	0.228	4.9 ± 0.3	20.1	349				
2131-021	048	0.558	0.664	0.023	933.4 ± 10301.7^{F}	18.7	94				
		0.558	0.612	0.085	12.9 ± 2.5^{P}	18.7	94				
		0.558	0.623	0.066	9.7 ± 1.3	18.7	94				
2131-021	080	0.734	0.685	0.144	29.7 ± 8.6^{F}	24.1	261	0.97	0.32	0.32	B
		0.734	0.842	0.009	9.7 ± 0.6	24.1	261				
		0.734	0.724	0.078	6.3 ± 0.4	24.1	261				
2131-021	145	0.685	0.668	0.082	948.5 ± 9967.8^{F}	19.0	278				
		0.685	0.864	0.002	10.0 ± 0.5	19.0	278				
		0.685	0.662	0.090	5.9 ± 0.4	19.0	278				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
2134+004	048	0.521	0.680	0.001	20.6 ± 1.9^F	19.5	244				
2134+004	080	0.946	1.195	0.000	86.3 ± 16.1^F	31.7	603	0.99	0.10	0.11	Q
2134+004	145	0.588	0.564	0.044	1218.8 ± 10105.0^F	24.4	474				
2136+141	048	0.246	0.324	0.012	522.6 ± 5636.5^F	10.5	36				
2136+141	080	0.502	0.652	0.011	20.7 ± 4.2^P	21.0	49	0.89	0.27	0.31	Q
2136+141	145	0.394	0.492	0.022	9.0 ± 1.8^P	11.0	50				
2145+067	048	1.260	1.753	0.000	33.0 ± 2.4^F	18.2	242				
2145+067	080	2.070	2.841	0.000	33.5 ± 1.1^F	31.5	740	0.97	0.38	0.38	Q
		2.070	1.558	0.187	10.1 ± 0.6	31.5	740				
2145+067	145	1.659	1.944	0.002	1001.3 ± 4549.1^F	20.0	614				
		1.659	1.290	0.195	8.5 ± 0.7	20.0	614				
2153+377	048	0.253	0.138	1.000	0.1 ± 0.0^F	14.5	49				
2153+377	080	0.143	0.102	1.000	0.3 ± 0.0^F	14.0	55	0.89	0.14	0.21	G
2153+377	145	0.053	0.030	1.000	0.1 ± 0.0^F	14.3	60				
2155-152	048	0.502	0.600	0.038	26.6 ± 10.1^F	18.7	63				
2155-152	080	0.571	0.615	0.035	29.5 ± 8.7^F	19.8	206	0.94	0.26	0.27	Q
2155-152	145	0.471	0.480	0.172	43.6 ± 30.0^F	19.0	114				
		0.471	0.496	0.116	5.3 ± 0.4	19.0	114				
2155-304	048	0.127	0.081	1.000	0.3 ± 0.0^F	18.4	70				
2155-304	080	0.153	0.082	1.000	119.5 ± 525.1^F	18.7	140	0.76	0.34	0.40	B
2155-304	145	0.114	0.081	0.975	22.3 ± 12.0^F	19.4	148				
2200+420	048	1.592	1.419	0.047	1064.1 ± 8017.8^F	21.3	741				
		1.592	1.532	0.021	7.8 ± 0.4	21.3	741				
		1.592	0.995	0.471	3.9 ± 0.2	21.3	741				
2200+420	080	2.292	1.781	0.072	52.9 ± 13.2^F	30.9	1208	0.95	0.50	0.51	B
		2.292	1.180	0.496	9.1 ± 0.7	30.9	1208				
		2.292	1.342	0.332	6.8 ± 0.3	30.9	1208				
		2.292	1.524	0.189	3.8 ± 0.1	30.9	1208				
2200+420	145	2.117	1.579	0.118	7.8 ± 0.4	24.7	1051				
		2.117	1.280	0.350	3.9 ± 0.1	24.7	1051				
2202+315	048	0.584	0.629	0.062	5.9 ± 0.5	17.1	142				
2202+315	080	1.071	1.267	0.004	15.0 ± 1.3^P	20.8	321	0.97	0.32	0.33	Q
		1.071	0.960	0.158	6.3 ± 0.4	20.8	321				
2202+315	145	1.053	1.246	0.008	16.8 ± 2.6^F	16.3	212				
		1.053	0.873	0.490	5.8 ± 0.6	16.3	212				

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
2223-052	048	0.764	0.784	0.025	17.9 ± 2.7^P	19.0	406				
		0.764	0.590	0.354	7.5 ± 0.8	19.0	406				
2223-052	080	1.333	1.175	0.060	26.9 ± 3.6^P	31.8	686	0.96	0.26	0.27	Q
		1.333	1.143	0.077	7.2 ± 0.3	31.8	686				
2223-052	145	1.632	1.200	0.285	19.2 ± 4.2^P	19.5	602				
		1.632	1.420	0.082	6.5 ± 0.4	19.5	602				
2229+391	048	0.104	0.072	1.000	0.2 ± 0.0^F	14.5	55				
2229+391	080	0.104	0.078	1.000	0.1 ± 0.0^F	14.0	50	0.81	0.12	0.20	G
2229+391	145	0.031	0.021	1.000	0.2 ± 0.0^F	14.3	61				
2230+114	048	0.344	0.333	0.077	882.2 ± 8977.2^F	17.6	305				
2230+114	080	0.510	0.469	0.029	37.9 ± 7.9^F	24.7	821	0.98	0.14	0.14	Q
		0.510	0.376	0.182	8.2 ± 0.5	24.7	821				
2230+114	145	0.759	0.813	0.006	974.0 ± 5264.3^F	19.5	708				
		0.759	0.619	0.111	8.5 ± 0.7	19.5	708				
		0.759	0.483	0.465	4.1 ± 0.2	19.5	708				
2243+394	048	0.115	0.081	1.000	0.8 ± 0.0^F	14.5	45				
2243+394	080	0.135	0.096	1.000	0.2 ± 0.0^F	13.6	53	0.87	0.06	0.16	G
2243+394	145	0.057	0.036	1.000	1.0 ± 0.1^F	14.3	56				
2251+158	048	2.301	1.598	0.426	12.3 ± 1.8	20.9	554				
		2.301	2.428	0.010	6.2 ± 0.2	20.9	554				
2251+158	080	3.933	2.466	0.261	1637.1 ± 16086.2^F	32.7	1175	0.97	0.31	0.31	Q
		3.933	2.501	0.245	13.6 ± 1.1	32.7	1175				
		3.933	3.676	0.014	6.7 ± 0.1	32.7	1175				
		3.933	2.419	0.283	4.6 ± 0.1	32.7	1175				
2251+158	145	2.767	1.864	0.273	11.8 ± 1.1	25.2	885				
		2.767	2.877	0.006	6.3 ± 0.2	25.2	885				
2254+074	048	0.129	0.138	0.273	15.0 ± 5.3^P	17.5	47				
2254+074	080	0.134	0.096	1.000	15.9 ± 8.2^F	19.6	79	0.93	0.25	0.31	B
2254+074	145	0.129	0.128	0.379	16.8 ± 5.6^P	19.3	79				
2335+031	048	0.085	0.058	1.000	0.4 ± 0.0^F	18.7	48				
2335+031	080	0.118	0.068	1.000	0.1 ± 0.0^F	19.4	65	0.75	0.22	0.32	G
2335+031	145	0.041	0.026	1.000	0.1 ± 0.0^F	18.1	56				
2345-167	048	0.438	0.425	0.508	61.7 ± 129.8^F	12.4	70				
2345-167	080	0.510	0.440	0.805	37.7 ± 31.6^F	20.3	92	0.96	0.21	0.24	Q
2345-167	145	0.391	0.509	0.018	1.8 ± 0.1	9.4	32				
2351+456	048	0.154	0.165	0.083	11.8 ± 1.9	18.9	129				
2351+456	080	0.179	0.124	1.000	984.2 ± 35121.0^F	19.7	69	0.95	0.14	0.19	Q
2351+456	145	0.190	0.150	0.821	13.5 ± 3.8^F	19.6	149				

3. Variability parameter

Blazars are variable in the entire electromagnetic wavebands. The variability violence can be expressed by the variability parameter. In the optical bands, the variability violence can be reported by using the variation parameters, such as variability parameter C introduced by Romero et al. (1999). In radio bands, the variability violence is discussed using the variability index (VI), the normalized variability amplitude(NVA), and the root mean square dispersion($RMSD$). We described these radio variation parameters below.

3.1. Variability index(VI)

The variability index that measures the peak-to-trough variations in our flux density measurements can be calculated as introduced by Aller et al. (1992, 2003); Ciaramella et al. (2004):

$$VI = \frac{(S_{max} - \sigma_{S_{max}}) - (S_{min} + \sigma_{S_{min}})}{(S_{max} - \sigma_{S_{max}}) + (S_{min} + \sigma_{S_{min}})}, \qquad (11)$$

where S_{max} and S_{min} are the peak and the lowest flux densities, and $\sigma_{\mathrm{S_{max}}}$ and $\sigma_{\mathrm{S_{min}}}$ are the associated measurement errors of the fluxes.

3.2. Normalized variability amplitude (NVA)

The normalized variability amplitude (NVA) was calculated in the following way. For each band, the mean $\langle X\rangle$ and standard deviation σ_{tot} of the flux points and the mean error level σ_{err} were determined (Edelson et al., 1996). Since the NVA is free of the instrumental effect, it is calculated as

$$NVA = \sqrt{\frac{\sigma^2_{\mathrm{tot}} - \sigma^2_{\mathrm{err}}}{\langle X\rangle^2}}. \qquad (12)$$

3.3. Root mean square dispersion (RMSD)

When a source has been observed at several epochs, whether the variability is a real one not can be determined by comparing the distribution of flux at the different epochs with a model in which the flux of the source is assumed to be non-variable (Edelson et al., 1992). If S_i represents the measured fluxes, then the mean flux $\langle S\rangle$ and the root mean square dispersion as a fraction of the mean are given by following equations, respectively,

$$\langle S\rangle = \frac{1}{N}\sum_{i=1}^{n} S_i \qquad (13)$$

$$\sigma = \frac{1}{\langle S\rangle}\sqrt{\frac{1}{N-1}\sum_{i=1}^{n}(S_i - \langle S\rangle)^2} \qquad (14)$$

$$\chi^2 = \frac{1}{N}\sum_{i=1}^{n}\left(\frac{S_i - \langle S\rangle}{\sigma_i}\right)^2 \qquad (15)$$

where σ_i is the uncertainty in the individual measurement, and $\chi^2 > 1$ indicates that the assumption of non-variable flux is questionable (Kembhavi & Narlika, 1999).

4. Results

Periodicity results and the variability parameters of radio galaxies are reported in Table 1, in which Col. 1 represents the name of the source, Col. 2 $Freq$, the frequency in units of GHz, Col. 3 δ_N, root mean square deviation, δ_N^2 is the total variance of data, Col. 4 A, the amplitude, Col. 5 the FAP of the determined period. Col. 6 Tms, the determined period in units of years. The superscript "F" means it is not a physically meaningful period ($FAP > 0.5$ or Tms > ObT), and the superscript "P" means it is a possible time scale ($FAP < 0.5$ and $\frac{2}{3}$ObT < Tms < ObT). Column. 7 ObT indicates the time coverage of the light curve in units of years, Col. 8 the data points (N), Col. 9 VI, Col. 10 NVA, Col. 11 RMSD, and Col. 12 the source identification (B for BL Lacertae, Q for flat spectrum radio quasar-FSRQ and G for galaxy).

For the whole and the subclass samples, the corresponding averaged values for the variability parameters are presented in Table 2. The results based on the mutual correlation between different variability parameters are reported in the Table 3 and plotted in Fig. 3.

The relationship between the variability parameters and brightness of the sources were determined by using the averaged 8 GHz flux density. The results are listed in Table 4 and the corresponding results are shown in the Fig. 4.

4.1. Periodicity in the radio light curves: Individual source

The long-term variability period analysis was done at other wavebands for some sources in the literature. Here we compare the radio results with published optical and other EM band results.

4.1.1. PKS 0219+428 (3C 66A)

In optical bands, a 65-day period was reported by Lainela et al. (1999). Long-term variability periods of 2.5 years (Belokon & Babadzhanyants, 2003) and 4.25±0.28 years (Fan et al., 2002a) were reported. In the present paper, no possible period can be found in the period analysis of the radio light curves.

4.1.2. AO 0235+164

A possible periodicity of ∼ 5.7 years was reported in the radio light curve by Roy et al. (2000) and Raiteri et al. (2001). Our result shows that there is a period of 5.7±0.3 years in 8GHz with $FAP = 0.452$ and 5.8±0.3 years in 14.5GHz with $FAP = 0.436$, which are quite consistent with the earlier result.

4.1.3. S5 0716+714

A periodicity of 5.5−6 years was found in the radio emission by Raiteri et al. (2003). Our result shows periods of 5.7 ± 0.5 years in 4.8GHz with $FAP = 0.200$ and 5.4 ± 0.3 years in 14.5GHz with $FAP = 0.117$, which are consistent with the earlier result.

4.1.4. PKS 0735+178

We report periods of 4.89 and 14.2 years in the optical band (Fan et al. 1997). The period of 4.89 years was also found by Webb et al.(1988). For the radio data, a period of 13.5 ± 0.9 years in 14.5GHz with $FAP = 0.003$ and possible periods of 12.9 ± 0.9 years in 4.8GHz with $FAP = 0.002$ and 15.0±1.2 years in 8GHz with $FAP = 0.011$ were found, which are quite consistent with the 14.2-year optical period.

Table 1. -Continued

Designation	Freq	δ_N	A	Fap	Tms	ObT	N	VI	NVA	RMSD	ID
2352+495	048	0.094	0.057	1.000	0.4 ± 0.0^F	14.5	57				
2352+495	080	0.140	0.101	1.000	62.3 ± 208.8^F	13.7	58	0.85	0.11	0.19	Q
2352+495	145	0.095	0.077	0.996	714.7 ± 22042.4^F	14.3	61				
2356+196	048	0.135	0.156	0.900	0.7 ± 1.0^F	0.7	3				
2356+196	080	0.102	0.100	0.900	0.2 ± 0.0^F	16.9	26	0.86	0.13	0.27	Q
2356+196	145	0.045	0.039	1.000	0.1 ± 0.0^F	2.0	22				

4.1.5. PKS 0754+100

The periods of 3.0 ± 0.35 and 17.85 years were found in our earlier paper (Fan et al., 2002a). In the present paper, periods of 6.6 ± 0.7 years in 4.8GHz with $FAP = 0.222$ and 6.8 ± 0.6 years in 14.5GHz with $FAP = 0.278$, 11.8 ± 2.3 years in 4.8 GHz with $FAP = 0.182$, 10.4 ± 0.8 years in 8GHz with $FAP = 0.014$, 11.3 ± 1.0 years in 14.5GHz with $FAP = 0.015$, and a possible period of 15.0 ± 3.6 years in 4.8GHz with $FAP = 0.167$ were also found. The 15.0 ± 3.6 year possible period is consistent with the optical result, 17.85 years.

4.1.6. PKS 0851+202 (OJ 287)

Sillanpaa et al. (1988) reported a 11.65-year period in the optical light curve. Periods of 5.53 ± 0.15 and 11.75±0.5 years were reported in our earlier paper (Fan et al., 2002a). But the radio light curve shows periods of 8.8 ± 1.0 years in 4.8GHz with $FAP = 0.445$ and 9.4 ± 0.6 years in 8GHz with $FAP = 0.266$, which is very different from the previously reported optical periods.

4.1.7. PKS 1219+285

A 14.85±1.55 year period was found in the optical band (Fan et al., 2002a). The present result shows a period of 10.4 ± 1.4 years in 8GHz with $FAP = 0.293$ and 10.0 ± 1.4 years in 14.5GHz with $FAP = 0.306$.

4.1.8. PKS 1226+023 (3C 273)

Periods of 2.0 years and 13.65±0.2 years were reported in the optical band. A possible period of 13.5 years was reported in the X-ray band by Manchanda (2002). The present work gives periods of 8.8 ± 0.3 years in 4.8GHz with $FAP = 0.001$, 8.3 ± 0.2 years in 8GHz with $FAP = 0.006$, and 8.2±0.2 years in 14.5GHz with $FAP = 0.001$.

4.1.9. PKS 1253-055 (3C 279)

The infrared light curve shows a period of 7.1±0.44 years (Fan, 1999). The present work shows periods of 5.1 ± 0.2 years with $FAP = 0.357$, 7.4±0.3 years with $FAP = 0.307$, 10.1±0.7 years with $FAP = 0.426$, and 15.1 ± 1.5 years with $FAP = 0.352$ in 8.0GHz. The 7.4±0.3 year period is quite consistent with what is found in the infrared band.

4.1.10. PKS 2155-304

Based on the optical light curves, periodicity of 4.6 and 7.0 years was reported (Fan & Lin, 2000). In the present paper, no possible period was found by power spectral analysis.

Table 2. Averaged variability parameters

Param. (1)	14.5GHz (2)	8GHz (3)	4.8GHz (4)
VI	0.92 ± 0.08	0.90 ± 0.09	0.90 ± 0.10
VI-BL	0.90 ± 0.10	0.88 ± 0.12	0.84 ± 0.14
VI-FSRQ	0.94 ± 0.05	0.92 ± 0.07	0.93 ± 0.06
VI-G	0.89 ± 0.09	0.90 ± 0.06	0.93 ± 0.05
NVA	0.23 ± 0.13	0.22 ± 0.12	0.16 ± 0.12
NVA-BL	0.30 ± 0.12	0.28 ± 0.11	0.24 ± 0.11
NVA-FSRQ	0.22 ± 0.11	0.21 ± 0.11	0.15 ± 0.11
NVA-G	0.10 ± 0.04	0.11 ± 0.05	0.04 ± 0.03
RMSD	0.27 ± 0.12	0.27 ± 0.11	0.23 ± 0.12
RMSD-BL	0.33 ± 0.11	0.32 ± 0.11	0.29 ± 0.11
RMSD-FSRQ	0.25 ± 0.10	0.24 ± 0.10	0.20 ± 0.10
RMSD-G	0.17 ± 0.03	0.20 ± 0.05	0.15 ± 0.03

Table 3. Correlation between variability parameters, $Y = aX + b$

$X - Y$ (1)	$a \pm \Delta a$ (2)	b $\pm \Delta b$ (3)	r (4)
V.I.–NVA	0.04 ± 0.06	0.89± 0.02	0.05
RMSD-NVA	0.84 ± 0.03	1.08± 0.01	0.893

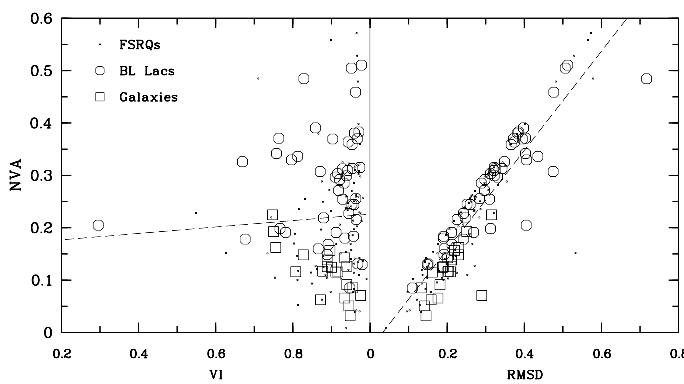

Fig. 3. Correlation between variability parameters. Left panel is for NVA and V.I., while the right panel is for NVA and RMSD.

4.1.11. PKS 2200+420 (BL Lacertae)

The optical periodicity was analyzed and found to be 14.0 years (Fan et al., 1998). The present work reports periods of 3.9 ± 0.2 years in 4.8GHz with $FAP = 0.471$, 3.8±0.1 years in 8GHz with $FAP = 0.189$, 3.9 ± 0.1 years in 14.5GHz with $FAP = 0.350$, 7.8 ± 0.4 years in 4.8GHz with $FAP = 0.021$, 6.8 ± 0.3 years in 8GHz with $FAP = 0.332$, and 7.8 ± 0.4 years in 14.5GHz with $FAP = 0.118$.

Table 4. Correlation between variability parameter and flux density, Vari = $a \log F_{8\mathrm{GHz}} + b$

Param. (1)	$a \pm \Delta a$ (2)	$b \pm \Delta b$ (3)	r (4)
$\log F_{8\mathrm{GHz}} - RMSD$	-0.04 ± 0.02	2.27 ± 0.01	-0.17
$\log F_{8\mathrm{GHz}} - NVA$	0.01 ± 0.02	1.41 ± 0.01	0.05
$\log F_{8\mathrm{GHz}} - VI$	0.132 ± 0.01	$0.88 \pm 5.7 \times 10^{-3}$	0.65

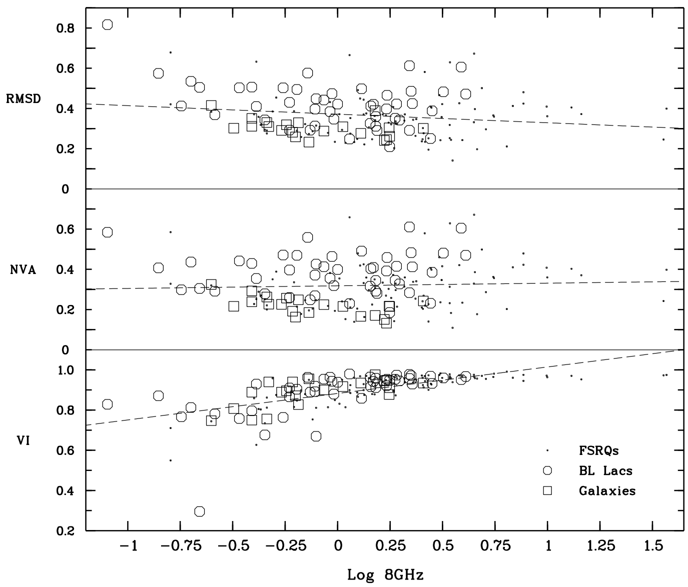

Fig. 4. Correlation between the variability parameter and radio brightness (averaged flux density). The upper panel indicates the relation between RMSD and the 8GHz flux density, the middle panel indicates the relation between NVA and the 8GHz flux density, and the lower panel indicates the relation between V.I. and the 8GHz flux density. The lines show the best fitting results mentioned in the text.

5. Discussions and conclusions

Blazars are variable over all electromagnetic wavelengths. Optical photometry is available for some blazars for about a century (Fan, 2005a). The radio monitoring program started much too late, only about 40 years ago. But the radio monitoring coverage is also long enough for the periodicity analysis and the variability property investigations.

There are 168 radio sources in the UMRAO data base, and the observation time coverage of the radio light curves is from 0.1 year for 1217+023 to 33.8 years for 1226+023 (3C 273). When the power spectral periodicity analysis method was adopted to the 4.8GHz, 8.0GHZ, and 14.5GHz light curves for the 168 sources, 203 astrophysically meaningful periods ($FAP < 0.50$ and Tms $< \frac{2}{3}$ObT) were obtained for 66 sources (see Table 1). The periods are different from one source to another, which is from 2.2 years for 0454-234 at 4.8 GHz to 20.8±1.2 years for 1641+399 at 8.0 GHz. There is no clear possible period sign found for the other 102 sources for which either the FAP is greater than 0.5 for the period or the period is 2/3 times longer than the observation time coverage (see Table 1, the superscript "F" means the period is not a physically meaningful one ($FAP > 0.5$ or Tms > ObT), and the superscript "P" means it is a possible time scale ($FAP < 0.5$ and 2/3ObT < Tms < ObT)). Here, we take the periods with $FAP > 0.5$ to have no physical meaning. In addition, if the determined period is 2/3 times longer than the observation time coverage, we did not take it as a physically meaningful period either. It can be mentioned that from data that is pure noise, any method of period estimation will yield some false probabilities in the period range that is roughly equal to the length of the data samples, or somewhat smaller.

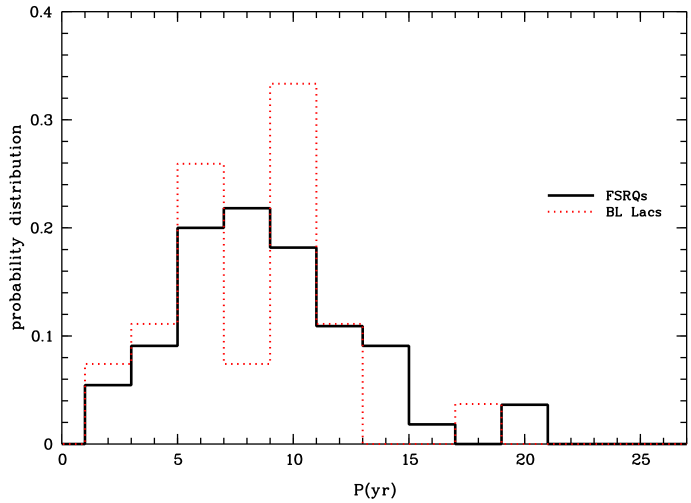

Fig. 5. Histogram of the periodicity, P (in units of years) at 8GHz for BL Lacertae objects and FSRQs. The dotted line stands for BLs and the filled line for FSRQs.

If we consider galaxie, FSRQs and BLs separately, we find that the physically significant periodicity at 8GHz are in the range of 2.2 to 20.8 years for FSRQs (55 physically meaningful periods for 34 objects) and from 2.5 to 18.0 years for BLs (27 physically meaningful periods for 17 objects). However, there is no physically significant periodicity found for galaxies. The average value of the periodicity is 8.9 ± 4.0 years for FSRQs and 8.1 ± 3.4 years for BLs. In Table 2 and Fig 4, we can see that RMSD and NVA for galaxies are lower than those for FSRQs and BLs. It is interesting that the sources with physically meaningful periods have higher RMSD and NVA.

Our results are also consistent with the results obtained by Ciaramella et al. (2004), who have analyzed the periodicity from the high-frequency radio data. The physically meaningful period histogram at 8GHz for the subclass samples of BLs and FSRQs are shown in Fig. 5. There is no clear difference in the possible periodicity distribution as shown in Fig. 6, in which the Kolmogorov-Smirnov (K-S) test indicates that the probability for the possible periodicity distributions of BL Lac objects and FSRQs coming from the same parent distribution is greater than 68.2%. If the possible periodicity is associated with the central structure, namely associated with the central black-hole mass, then the similar possible periodicity distribution for FSRQs and BLs should suggest that their central black-hole masses show a similar distribution. In fact, no clear difference was found in the central black-hole masses of BLs and FSRQs (Fan, 2005b).

From the sources listed in Sect. 4.1, we can see that the periods found in the optical bands were not always consistent with those found in the radio bands. Some sources show similar radio and optical variability periods: 0735+178 show a significant radio period of 13.5 ± 0.9 years and two possible radio periods of 12.9±0.9 and 15.0±1.2, and an optical period of 14.2 years, 0754+100 shows a possible radio period of 15.0 ± 3.6 years and an optical period of 17.85 years, 1253-055 shows radio periods of 7.1 to 7.4 years and an infrared period of 7.1 ± 0.44 years for instance. Meanwhile some others show different possible periods(OJ 287, 1226+023(3C 273), 2200+420 for instance. This

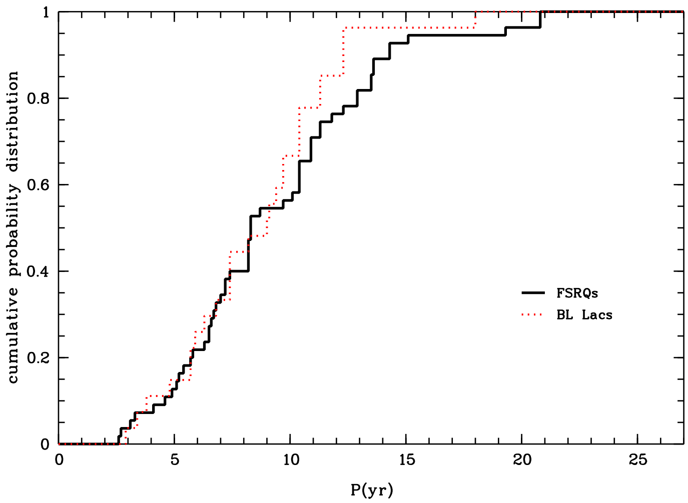

Fig. 6. Accumulative results for the periodicity (in units of years) at 8GHz for BL Lacertae objects and FSRQs. The dotted line stands for BLs and filled line for FSRQs.The Kolmogorov-Smirnov test indicates that the probability for the possible periodicity distributions of BL Lac objects and FSRQs coming from the same parent distribution is 68.2%.

difference is perhaps from the fact that the light curves used for the possible periodicity analysis were not long enough in some sources, or the variation in the radio bands and optical bands were caused by different mechanisms as noticed in the case of OJ 287, and the observed optical outbursts were not correlated with those observed in the radio band (Takalo, 1998). For some cases, it is possible that the lack of agreement between optical and radio possible periods is due to the fact that one or the other is spurious, just due to noise.

For AGNs, the variability mechanism is not yet well understood. Some models have been proposed to explain the optical long-term possible periodic variations: the binary black-hole model, the thermal instability model, and the perturbation model (Fan, 2005a). The promising models are the binary black-hole model and the perturbation model. The helical jet related with the binary black holes have been used to explain the optical variability behavior for the objects (3C 345, OJ 287, BL Lacertae, and PKS 0735+178). It has been claimed that the possible periodicity in the historical light curves also show helical trajectories in their VLBI radio components (Villata & Raiteri, 1999). In this sense, one would expect similar possible periodicity behavior in optical and radio bands, which has been confirmed for many sources in our analysis. In the radio bands, the variability is explained by various mechanisms (Ciaramella et al., 2004) such as shocks in jets, changes in the direction of forward beaming, and precession in a binary black-hole system (Marscher & Gear, 1985; Aller et al., 1985; Camenzind & Krockenberger, 1992; Begelman et al., 1980; Rieger & Mannheim, 2000, 2003).

The variability parameters viz. variability index VI, normalized variability amplitude NVA, and RMSD are listed in the Table 2, in which *W* stands for the whole sample. These parameters show that the sources are variable, and NVA and RMSD are correlated. On the other hand, no correlation was found in the VI parameter with NVA or RMSD (see Table 3, Fig. 3). This suggests that NVA and RMSD are more reliable for the variability indication than the VI. Therefore, we suggest using NVA and RMSD for indicating variability violence, if possible. It is also easily found that the variability parameter at higher frequency is greater than those in the lower frequency.

However, for the correlation between the variability parameter and the flux density, we found that the relationship between the source brightness and NVA and/or RMSD is not as close as the one between the source flux density and VI (see Fig. 4 and Table 4). We think that the correlation between the source brightness and VI is an apparent result, since the VI and the brightness (namely the averaged flux density) are more associated with the maximum flux density when the difference between the maximum and the minimum is big enough, which will result in an apparent correlation. Therefore, we do not think that there is a correlation between the brightness and the variability in the radio bands.

When we considered BLs and FSRQs separately, we found that the NVA and RMSD of BLs are larger than those of FSRQs, and the NVA and RMSD of BLs and FSRQs are larger than those of galaxies. This finding suggests that BLs are more variable than FSRQs in the radio bands. In addition, there is a tendency for the variability parameter to increase with the frequency for the whole sample and the individual BLs and FSRQ sub-samples. This tendency is also found in the optical bands.

In the present paper, the power spectral (Fourier) periodicity analysis method was adopted to a large sample of radio sources given in UMRAO. The results show that the possible periodicity is present in the range of 2.2 to 20.8 years for 66 radio sources. BLs are more variable than FSRQs and the variability parameters depend on the frequency.

Acknowledgements. The authors thank the referee for the constructive comments and suggestions. This work is partially supported by the National 973 project (NKBRSF G19990754), the National Science Fund for Distinguished Young Scholars (10125313), the National Natural Science Foundation of China (10573005, 10633010), and the Fund for Top Scholars of Guangdong Province (Q02114). We also thank the financial support from the Guangzhou Education Bureau and Guangzhou Science and Technology Bureau. ACG's efforts are partially supported by the Department of Atomic Energy, Govt. of India. This research made use of data from the University of Michigan Radio Astronomy Observatory, which is supported by the University of Michigan and the National Science Foundation.

References

Aller, H.D., Aller, M.F., & Hughes, P.A. 1985, ApJ, 298, 296
Aller M.F., Aller, H. D., Hughes, P. A., 1992, ApJ, 399, 16
Aller M.F., Aller, H. D., Hughes, P. A., 2003, ApJ, 586, 33
Begelman, M.C., Blandford, R.D., & Rees, M.J. 1980, Nat., 287, 307
Belokon, E. T.,& Babadzhanyants, M. K., 2003, Heba. Conf. p205,
Bondi, M., Padrielli, L., Fanti, R., et al., 1996, A&AS, 120, 89
Camenzind, M., & Krockenberger, M. 1992, A&A, 255, 59
Ciaramella, A.; Bongardo, C.; Aller, H. D,et al 2004,A&A 419 485
Edelson R.P., et al. 1992, ApJS, 83, 1
Edelson, R.A., Alexander, T., Crenshaw, D.M. et al. 1996, ApJ, 470, 364
Fan J.H., 2005a, ChJAA, 5S, 213
Fan J.H., 2005b, A&A, 436, 799
Fan J.H., et al. 2002a, A&A, 381, 1
Fan, J.H., Cheng K.S., Zhang L., 2002b, PASJ, 54, No. 4, 533
Fan J. H., & Lin R. G., 2000, A&A, 355, 880
Fan J.H., 1999, MNRAS, 308, 1032
Fan J.H., Xie G.Z., Pecontal E. et al. 1998, ApJ 507, 178
Fan J.H., Xie, G.Z., Lin R.G., 1997, A&AS, 125, 525
Ferraz-Mello, S, 1981, AJ, 86, 619
Foster, G. 1995, AJ, 109, 1889
Horne, J., & Baliunas, S. 1986, ApJ, 302, 757
Jurkevich, I. 1971, Ap&SS 13, 154
Kembhavi A.K. & Narlika J.V., 1999, Quasars and Active Galactic Nuclei, Cambridge Uni. Press
Kidger M.R., Takalo L., Sillanpaa A. 1992, A&A 264, 32
Kraus A., Quirrenbach A., Lobanov A.P. et al., 1999, A&A 344, 807
Lahteenmaki, A., & Valtaoja, E., 1999, ApJ, 521, 493
Lainela, M., Takalo, L. O., Sillanpaa, A., et al., 1999, ApJ, 521, 561
Manchanda, K. R., 2002, JApA, 23, 243
Marscher, A.P., & Gear, W.K. 1985, ApJ, 298, 114

Raiteri, C.M., Villata, M., Tosti, G., et al. 2003, A&A, 402, 151
Raiteri, C.M., Villata, M., Aller, H.D., et al. 2001, A&A, 337, 396
Rieger, F. M. & Mannheim, K., 2000, A&A, 359, 948
Rieger, F. M. & Mannheim, K., 2003, A&A, 397, 121
Romero G.E., et al. 1999, A&AS, 135, 477
Roy, M., Papadakis, I.E., Ramos-Colon, E., Sambruna, R., et al. 2000, ApJ, 545, 758
Scargle, J. 1982, ApJ, 263, 835
Sillanpaa, A., Haarala, S., Valtonen, M.J., Sundelius, B., & Byrd, G.G. 1988, ApJ, 325, 628
Takalo, L. O. 1998, A&AS, 129, 577
Tornikoski, M., Valtaoja, E., Teräsranta,H., et al. 1996, A&AS, 116, 157
Villata M. & Raiteri C.M. 1999, A&A, 347, 30
Webb, J. R., Smith, A. G., Leacock, R. J., et al. 1988, AJ, 95, 374

List of Objects